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THE MASS DIAGRAM IN TIMBER ACCESS ROAD ANALYSIS

by

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ABSTRACT

Much of the damage caused by timber access roads results from sidecasting of surplus material, a construction practice that has caused stream sedimentation, road failures, and mass soil movements. Recent restrictions on the use of sidecasting require end hauling excess materials, a practice that can increase road construction cost 10 to 30 percent. In the early stages of road planning, the mass diagram is useful in locating the best route to reduce end haul costs and sidecasting. A procedure is presented that will produce a rapid and accurate mass diagram plot from preliminary planning data.

Keywords: Access road system planning, computers.

INTRODUCTION

Mounting pressures on government and private timber managers to reduce the detrimental impact of roads have resulted in a number of modified construction practices. Most notable among these is the end hauling requirement. The purpose of end hauling is to eliminate indiscriminate sidecasting of surplus excavated materials, which are a common source of stream sediments, road embankment failures, and other forms of mass soil movement.

To evaluate the probable impact of end hauling, it would be useful to have an indication of total volumes of excavation and embankment, accumulative volumes, and their locations along the roadway. This information is conveniently provided by the mass diagram and can be provided early in the planning stages of access road location.

Automated analysis of timber access road locations has been discussed in an earlier paper.[1/] The purpose of this paper is to provide a mass diagram and a procedure for implementing the diagram as an addition to General Technical Report PNW-27. This information will be of use to logging and civil engineers, transportation planners, and others involved with the planning, location, and design of timber access roads.

The mass diagram is most often used to determine proper distribution of excavated material, to determine amount and location of waste and borrow materials, and to estimate the costs of borrow and haul of other excavated materials. This paper does not cover details of these procedures.

MASS DIAGRAM

The mass diagram is a plotted curve with the distance along the roadway for the abscissa and the algebraic sums of earthwork quantities for the ordinates. Excavation quantities are considered positive and embankment quantities, negative. The ordinate at the beginning of the curve is zero, and all subsequent ordinates are calculated continuously from that point.

As a brief review, the mass diagram has the following properties:

1. The ordinate at any point on the curve represents the algebraic accumulation of yardage to that point adjusted for shrinkage or swell--excess excavation if above the abscissa and excess embankment if below.

2. The difference in the lengths of any two ordinates is equal to the algebraic difference between excavation and embankment quantities between the two stations at which the ordinates are located.

3. Ascending lines represent excess excavation; descending lines represent excess fill.

4. Convex loops indicate that the haul from excavation to embankment is from left to right; concave loops indicate the haul is in the opposite direction.

EFFECTS OF SIDECASTING

It is difficult to limit fill-slope length or estimate the limits of downslope movement of sidecast excess materials in areas where the sideslope angle approximates the natural angle of repose of excavation or embankment materials. Embankment or sidecast materials tend to run downslope,

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[1/] Doyle Burke. Automated analysis of timber access road alternatives. USDA Forest Service General Technical Report PNW-27, 40 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., 1974.

seeking their angle of repose and creating sliver fills (fig. 1). Sliver fills are difficult to control, are expensive to construct, and tend to eliminate natural vegetation over the affected downslope area. They open large areas of mineral soil to erosion, are usually difficult to stabilize by seeding and mulching, and are visually unattractive. Unstabilized sliver fills can contribute to various types of soil mass movements associated with road failures.

End hauling has become a common practice to avoid the problems associated with sidecasting roadway materials or constructing sliver fills. It can increase road construction costs by 10 to 30 percent. Depending on the type of excavated material (rock, common, etc.), end hauling is typically specified where side slopes exceed 50 percent. Under current end haul requirements and costs, many roads constructed in past years might not be constructed today, or they would require major relocation to avoid steep side slopes.

Route locations that minimize sidecasting and end hauling are certainly preferred over those that do not. It is best to evaluate these items early in the planning stage.

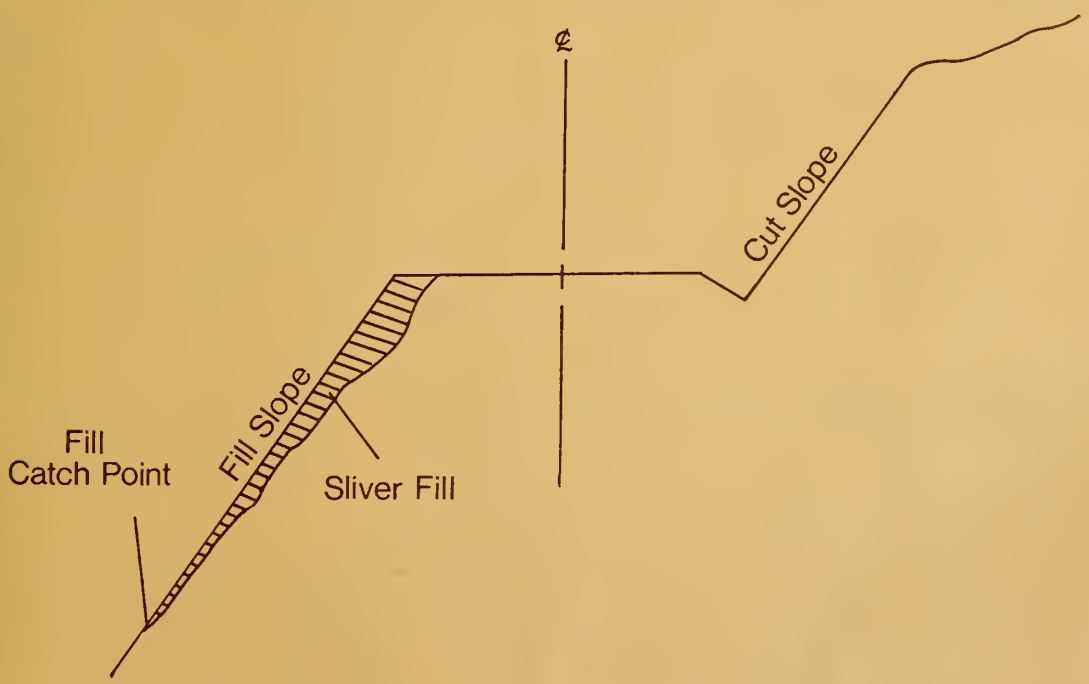

Figure 1.--Diagram of road section with sliver fill.

PLANNING CONSIDERATIONS

Indiscriminate sidecasting of excavated materials and sliver fill construction should be avoided. Ordinarily these factors are treated during final design of the roadway, but in many cases these problems can be reduced by considering the amount and location of materials in the planning process. Indeed, the amount and location of roadway materials may be the deciding factor in selecting among alternate routes.

Figures 2 and 3 illustrate the profile and mass diagram of two possible routes being considered for access to a timber harvest area. Both routes are approximately the same length and traverse locations with similar side slopes. From values shown in table 1, the route alternative of figure 2 would seem more desirable. However, examining the mass diagrams reveals the route alternative in figure 2 has a severe end haul situation, in both length of haul and mass of material. If no further adjustments in horizontal or vertical alinement are practical, the route shown in figure 3 could be more desirable than that of figure 2 if the cost of extra excavation is less expensive.

The decision to end haul should not be taken lightly because of the costs involved. Hence, identification of route locations with minimum end haul problems should be an objective in the planning stages of timber harvest design. The following mass diagram routine provides accurate and rapid plotting, using information preprocessed by the automated timber access road analysis package presented in General Technical Report PNW-27.

Table 1.--*Comparison of design considerations of routes shown in figures 2 and 3*

Design consideration	Route alternatives in:	
	Figure 2	Figure 3
Length (feet)	9,329	9,373
Average side slope (percent)	53	55
Ground profile	Uniform	Moderately broken
Excavation (cubic yard)	27,627	31,169
Embankment (cubic yard)	27,531	33,321
Maximum adverse (percent)	0	-0.7
Maximum favorable (percent)	4.1	7.8
Total clearing	10.89	11.91

NOTE: For both routes:

Subgrade width = 18 feet
Cut slope = 1:1
Fill slope = 1½:1
Extra clearing on cuts = 5 feet
Extra clearing on fills = none.

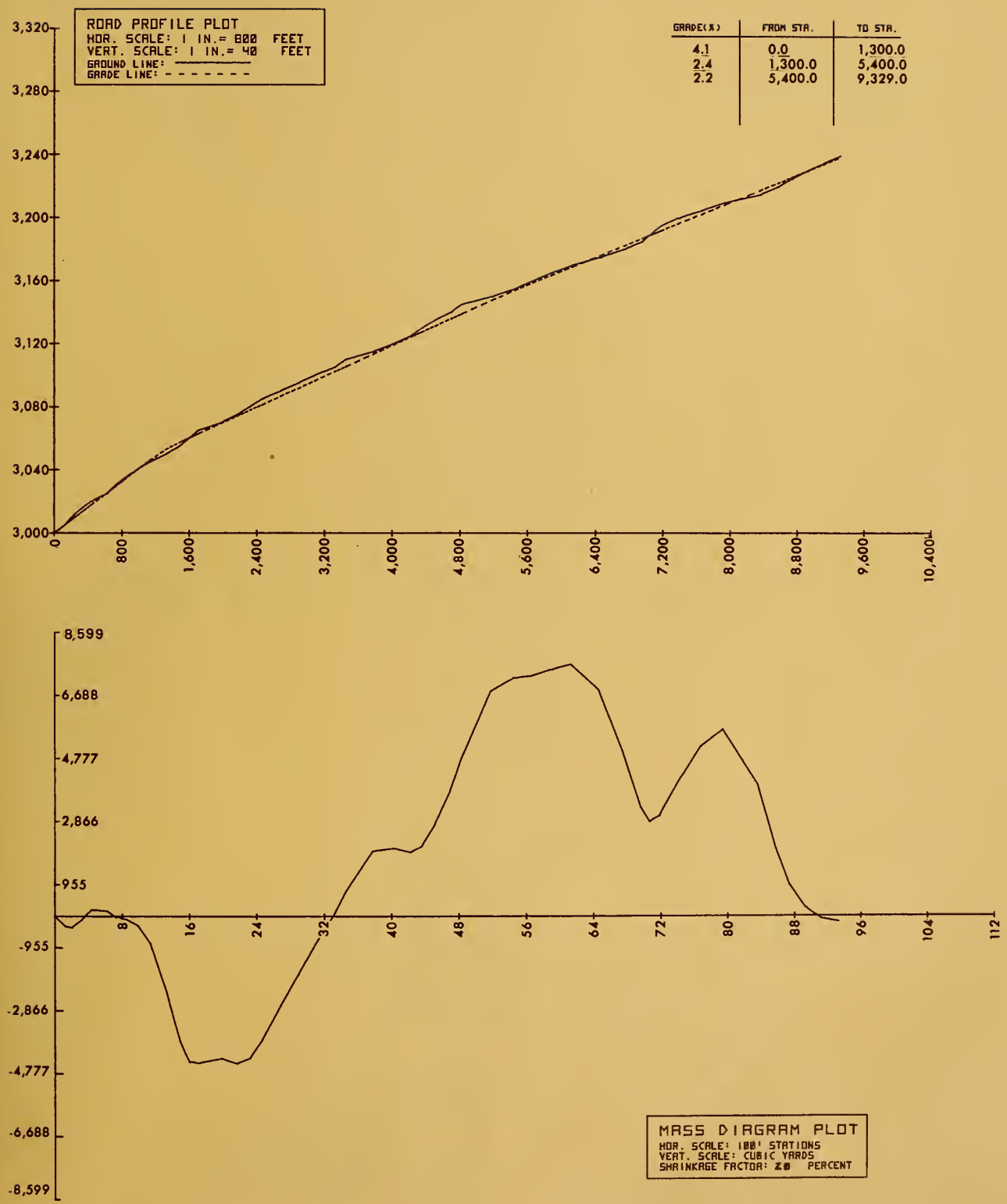

Figure 2.--Road profile and mass diagram plot of road location No. 1.

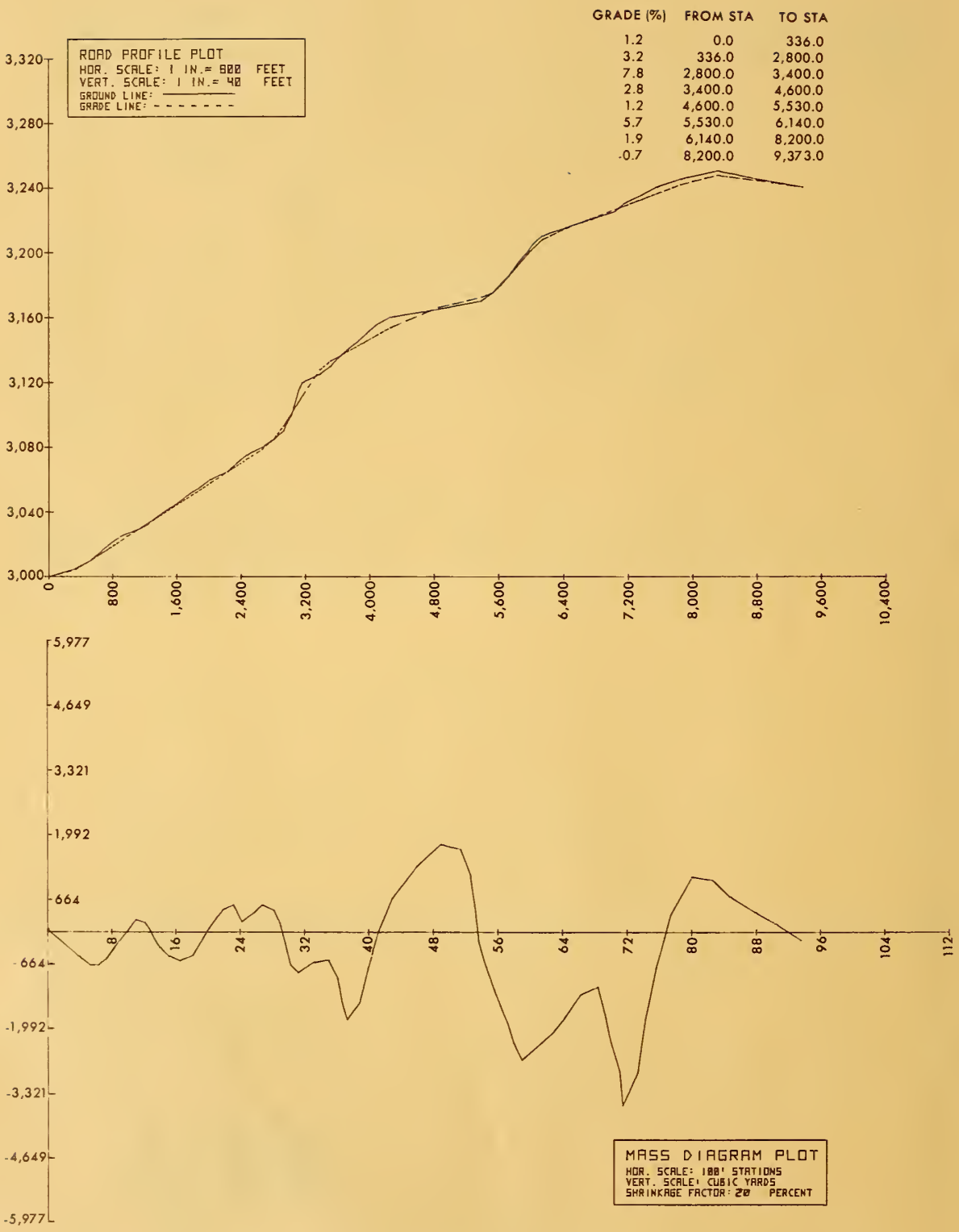

Figure 3.--Road profile and mass diagram plot of road location No. 2.

GENERAL LOGIC AND SETUP

The generalized logic for the mass diagram routine is illustrated in figure 4.

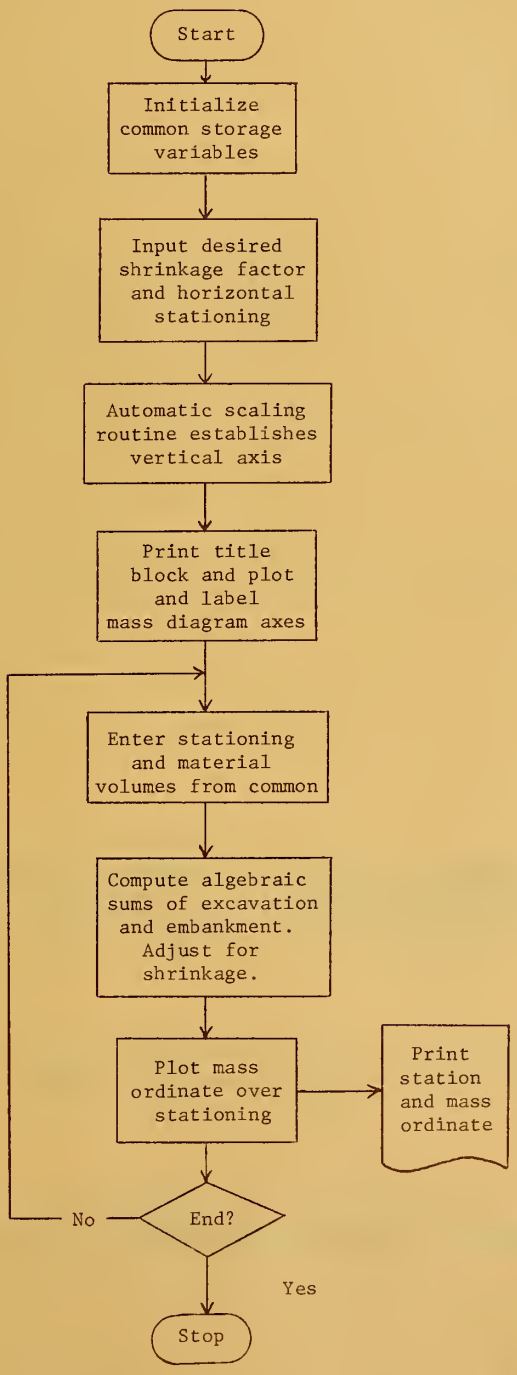
Start
Initialize common storage variables
Input desired shrinkage factor and horizontal stationing
Automatic scaling routine establishes vertical axis
Print title block and plot and label mass diagram axes
Enter stationing and material volumes from common
Compute algebraic sums of excavation and embankment. Adjust for shrinkage.
Plot mass ordinate over stationing
Print station and mass ordinate
End?
No
Yes
Stop

Figure 4.--Mass diagram flow chart.

The method presented in this note was developed for a Hewlett-Packard 9830[2/] calculator system; use of the method requires a knowledge of the system and initializing procedures. The mass diagram program, written in BASIC, should be entered on File 5. Special Function Key 9 should contain *LOAD 5,1,1*. Special Function Key 3 should contain *LOAD 6,1,1,*. All other keys remain unchanged.

Tape files should be organized as follows:

File	Contents
0	Control
1	Keys
2	Road projection routine
3	Horizontal alinement routine
4	Vertical alinement routine
5	Mass diagram routine
6	Earthwork routine

The "timber access road pac" overlay card is shown in figure 5.

[2/] The use of trade, firm, or corporation names in this publication is not an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.

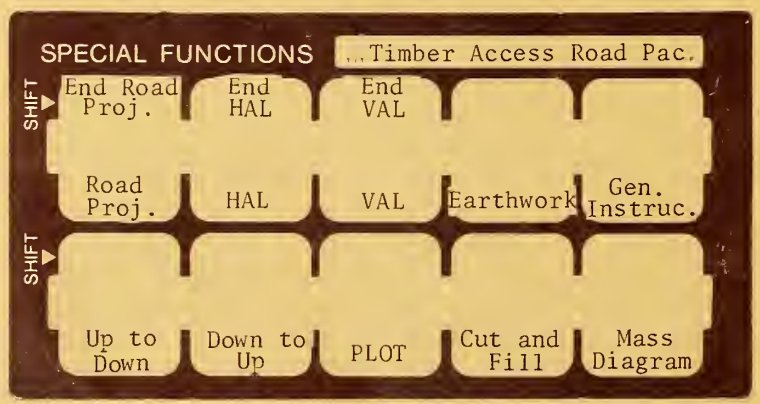

Figure 5.--"Timber access road pac" overlay card.

OPERATING INSTRUCTIONS

1. The mass diagram routine processes earthwork data produced and stored in common by the earthwork routine. A prior earthwork run is required.

2. Press S.F. Key 9.

3. Place paper on the plotter. Make sure plotting area is set for 9 x 14 inches.

4. Enter fill shrinkage, percent, EXECUTE.

5. Enter horizontal distance scale, feet per inch, EXECUTE. (Usually the same horizontal scale as the vertical alinement plot.)

6. The plotter will print the title block, draw and label the axes, and print the stationing and mass ordinates. Typical mass diagram plots are shown in figures 2 and 3.

VARIABLES USED IN THE MASS DIAGRAM ROUTINE, TAPE FILE 5

AS(I,1) = common storage for stationing

AS(I,2) = common storage for ground elevation

B(1) = common storage for station

B(2) = common storage for ground elevation

B(3) = common storage for grade elevation

CØ = counter

GS(I,1) = earthwork stationing

GS(I,2) = excavation yardage

GS(I,3) = embankment yardage

S = shrinkage percent

H = horizontal distance scale

A = counter

Y, Y1, Y2 = sorting variables in autoscaling function

I = counter

V = vertical yardage scale

X = stationing value

```
1 COM AS[ 1ØØ,2],BS[3],CØ,GS[2ØØ,3]
11 DISP "ENTER FILL SHRINKAGE (%)";
21 INPUT S
31 S=(S*Ø.Ø1)+1
41 DISP "ENTER HOR. DISTANCE SCALE";
51 INPUT H
61 REM AUTO Y SCALING ROUTINE
71 Y=Ø
76 A=Ø
81 FOR I=1 TO CØ
86 Y2=Y
91 Y1=(G[I,2]-G[I,3]*S)
1Ø1 Y=Y+Y1
111 IF ABSY>ABSY2 THEN 141
131 GOTO 151
141 IF ABSA>ABSY THEN 151
146 A=ABSY
151 NEXT I
156 V=A/4
161 DEG
171 SCALE Ø,14*H,-4.5*V,4.5*V
181 PLOT 9*H,-3.5*V
191 LABEL (*)"MASS DIAGRAM PLOT"
2Ø1 LABEL (*,1.1,1.7,Ø,9/14)"HOR. SCALE:  1ØØ' STATIONS"
211 LABEL (*,1.1,1.7,Ø,9/14)"VERT. SCALE: CUBIC YARDS"
221 LABEL (*,1.1,1.7,Ø,9/14)"SHRINKAGE FACTOR:"(S-1)*1ØØ"PERCENT"
231 PLOT 8.8*H,-3.2*V,-2
241 PLOT 12.1*H,-3.2*V,-2
251 PLOT 12.1*H,-4.2*V,-2
261 PLOT 8.8*H,-4.2*V,-2
271 PLOT 8.8*H,-3.2*V,-2
281 PEN
291 XAXIS Ø,H,Ø,14*H
3Ø1 YAXIS Ø,V,-4.5*V,4.5*V
311 FIXED Ø
321 FOR X=H TO 14*H STEP H
331 PLOT X,-V/2.5,-1
341 CPLOT Ø,-Ø.3
351 LABEL (*,1,1.7,9Ø,9/14)X/1ØØ
361 NEXT X
371 FOR Y=-4.5*V TO 4.5*V STEP V
381 PLOT 5Ø,Y,-1
391 CPLOT Ø,-Ø.3
4Ø1 LABEL (*,1,1.7,Ø,9/14)Y
411 NEXT Y
421 Y=Ø
425 PRINT "STATION     ORDINATE (CU.YD.)"
431 FOR I=1 TO CØ
441 X=G[I,1]
451 Y1=(G[I,2]-G[I,3]*S)
461 Y=Y+Y1
471 PLOT X,Y
475 PRINT X,Y
491 NEXT I
5Ø1 PEN
511 STOP
```

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Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

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2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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Portland, Oregon 97208

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